

CONTENT OF CARBON, NITROGEN AND SELECTED HEAVY METALS IN COMPOSTS

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Abstract

Chemical composition of composts depends on a number of factors, including a type of composted waste and composting technology. This study was conducted to determine concentrations of carbon, nitrogen and selected heavy metals in composts manufactured from various waste substances and using different technologies. Organic carbon content in the composts depended on a type of composted waste - the smallest quantities were found in the compost of municipal waste. Organic matter transformations occurring during composting probably led to a systematic decline of the soluble organic compound amounts. The share of soluble carbon in the total concentration did not exceed 35% of the analysed composts. The composts based on plant waste were more abundant in nitrogen and the share of nitrogen extracted with sodium pyrophosphate and sodium base did not exceed 40%. Analysis of fractional composition of humus compounds of the composts revealed higher content of humic acid carbon in relation to fulvic acid carbon. The proportion of non-hydrolysing carbon in these materials was on average over 70%. The content of the most mobile heavy metal forms in the composts was low and implied that these elements occurred in a form less available to plants.

Key words: composts, organic carbon, nitrogen, heavy metals.

ZAWARTOŚĆ WĘGLA I AZOTU ORAZ WYBRANYCH METALI CIĘŻKICH W KOMPOSTACH

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Skład chemiczny kompostów zależy m.in. od rodzaju kompostowanych odpadów, ale może być także uwarunkowany technologią kompostowania. Dlatego celem podjętych badań było określenie zawartości węgla, azotu oraz wybranych metali ciężkich w kompostach produkowanych z różnych substancji odpadowych i według różnych technologii. Zawartość węgla organicznego w kompostach zależała od rodzaju kompostowanego odpadu – najmniej tego składnika stwierdzono w kompoście z odpadów komunalnych. Przemiany materii organicznej zachodzące podczas kompostowania prowadziły do systematycznego zmniejszania się ilości rozpuszczalnych związków organicznych. W badanych kompostach udział węgla rozpuszczalnego w zawartości ogólnej nie przekraczał 35%. Zasobniejsze w azot były komposty z odpadów roślinnych, a udział azotu wyekstrahowanego pirofosforanem sodu i zasadą sodową nie przekraczał 40%. Analiza składu frakcyjnego związków próchnicznych badanych kompostów wykazała, w każdym przypadku, większą zawartość węgla kwasów huminowych w stosunku do zawartości węgla kwasów fulwowych. Udział węgla niehydrolizującego w tych materiałach wynosił średnio ponad 70%. Zawartość najbardziej mobilnych form metali ciężkich w kompostach była niewielka, co wskazuje na występowanie tych pierwiastków w postaci związków trudniej dostępnych dla roślin.

Słowa kluczowe: komposty, węgiel organiczny, azot, metale ciężkie.

INTRODUCTION

Composting is a natural process, which constantly occurs in the environment. It completes the organic substance cycle in nature. The growth of industry and progressing urbanisation in the world contribute to a rapid development of techniques and technologies of composting. As composting has become profitable, today even large manufacturers are interested in it. Modern technologies make it possible to produce composts from various kinds of waste, whose utilisation may be universal.

Macro- and microelements and organic matter contained in composts may contribute to improvement of physical, chemical and biological properties of soil, thus increasing its fertility, which undoubtedly determines the quality of the biomass obtained (SZULC et al. 2004, GAJ, GÓRSKI 2005). Considerable variability of waste chemical composition, frequently burdened with toxic substances, affects compost quality, which is crucial for its final destination. Determination of chemical composition of composts, including heavy metal concentrations, allows for assessment of these substances and their usefulness for agriculture. However, chemical composition determination does not encompass bioavailability of heavy metals after compost has been added to the soil. According to KABATA-PENDIAS et al. (1987), determining the rate of heavy metal mobilisation from waste substances is most important for agricultural practice as it allows to assess the speed at which these elements pass into soil solution and, consequently, their uptake by plants. As reported by CZEKAŁA et al. (1999) and DROZD et al. (1999), bioavailability of trace elements in wastes may be diminished by composting because certain amounts of trace elements become embedded in transforming organic material,

which causes their periodical immobilisation. Chemical composition of composts depends, among other factors, on a type of composted wastes but may be also conditioned by a composting technology. Therefore, this research has been conducted to determine the content of carbon, nitrogen and selected heavy metals in composts manufactured from various waste substances and using different technologies.

MATERIAL AND METHODS

Compost samples originated from three composting plants different in types of composted waste and technologies of composting. Compost (A) came from a composting plant where Mut Kyberferm system was applied; compost (B) originated from a plant where waste was composted using Horstmann technology, while compost (C) was produced by Dano technology. Compost (A) was manufactured from green waste and other biodegradable waste; compost (B) was obtained solely from plant waste, while compost (C) was based on municipal wastes. Farmyard manure and peat were treated as reference material for the analysed features.

The following assessments were made in the organic materials with natural water content: pH in water suspension by a potentiometer, electrolytic conductivity by a conductometer, and dry matter content after sample drying at 105° for 12 h (BARAN, TURSKI 1996). In the dried and ground material, organic carbon concentration was assayed by Tiurin method. The content of soluble carbon and humus compound fractions were determined after extraction of organic material with a mixture of 0.1 mol·dm⁻³ Na₄P₂O₇ + 0.1 mol·dm⁻³ NaOH. In the extracts total carbon was determined (by Tiurin method) and humic acid carbon was analysed after precipitation with concentrated H₂SO₄ (d = 1.84). The concentration of fulvic acid carbon was computed from the difference between the total organic carbon content in the extract and its quantity in humic acids. The concentrations of total nitrogen and nitrogen in alkaline extract (0.1 mol·dm⁻³ Na₄P₂O₇ + 0.1 mol·dm⁻³ NaOH) were determined by Kjeldahl method in a II Plus Kjeltec apparatus (Tecator) after reduction of N-NO₃⁻. Redistilled water and 0.05 mol·dm⁻³ CaCl₂ solution were used for isolating mobile fractions of heavy metals by McLaren and Crawford method modified by BOGACZ (1996). Heavy metal concentrations were assessed in the extracts by ICP-AES method in JY 238 Utrace apparatus (Jobin Yvon). The final results are means from two simultaneous replications. Standard deviation was computed for the obtained values.

RESULTS AND DISCUSSION

Dry matter content in the analysed composts was varied and depended on a type of composted material and composting technology (Table 1). Although the amount of dry matter in compost (A) was the lowest among all the composts, it was higher than in peat and farmyard manure.

Reaction is one of the most important physicochemical features of waste substances. No major differences were found in the reaction of the analysed composts, but pH values were higher in the composts than in peat or farmyard manure (Table 1).

The excess of soluble salts in waste used in the environment may cause total fallout of plants or development of numerous diseases. Electrolytic conductivity of waste is a good measure of salinity (BARAN, TURSKI 1996). The value of electrolytic conductivity in the analysed composts and peat did not exceed $2.9 \text{ mS}\cdot\text{cm}^{-1}$ (Table 1). Much higher values of this parameter were registered in farmyard manure.

The biggest quantities of organic carbon were determined in peat ($419 \text{ g}\cdot\text{kg}^{-1}$ d.m.) and farmyard manure ($330 \text{ g}\cdot\text{kg}^{-1}$ d.m.) – Table 2. Lower contents of organic carbon were found in composts and the smallest ones in compost (C) from municipal waste ($112 \text{ g}\cdot\text{kg}^{-1}$ d.m.). As results from the studies by DROZD et al (1996a), transformations occurring while composting organic matter diminish amounts of soluble organic compounds. These authors found that after 30 days of transformation the quantity of soluble carbon in compost from municipal waste constituted only 20% of the content assessed in the initial material. In the opinion of CHANYASAK, KUBOT (1981) the direction and rate of humus

Table 1
Tabela 1

Some properties of the analysed organic materials
Wybrane właściwości badanych materiałów organicznych

Determination Oznaczenie	Peat Torf	FYM Obornik	Compost – Kompost			SD**
			A*	B*	C*	
Dry matter Sucha masa $\text{g}\cdot\text{kg}^{-1}$ d.m. /s.m.	408	189	442	643	567	155
pH H ₂ O	7.99	8.40	9.52	10.68	9.90	0.98
Electrolitical conductivity Przewodność elektrolityczna $\text{mS}\cdot\text{cm}^{-1}$, 25°C	0.36	6.46	0.43	2.83	1.88	2.24

* A – compost from plant and other biodegradable waste – kompost z odpadów roślinnych i innych biodegradowalnych,

B – compost from plant waste – kompost z odpadów roślinnych

C – compost from municipal waste – kompost z odpadów komunalnych

** SD – standard deviation – odchylenie standardowe

Table 2
Tabela 2Carbon and nitrogen content in the analysed organic materials ($\text{mg} \cdot \text{kg}^{-1}$ d.m.)
Zawartość węgla i azotu w badanych materiałach organicznych ($\text{mg} \cdot \text{kg}^{-1}$ s.m.)

Determination Oznaczenie	Peat Torf	FYM Obornik	Compost – Kompost			SD**
			A*	B*	C*	
Org. C – C org.	419	330	251	201	112	118
Total N – N og.	33.3	29.2	37.5	17.4	8.7	11.9
C:N	12.6	11.3	6.7	11.6	12.9	2.5
C extracted C wyekstrahowany	75.2	95.0	80.0	48.1	19.2	30.0
%***	18	29	32	24	17	-
N extracted N wyekstrahowany	7.17	13.0	14.9	6.5	2.01	5.2
%***	22	45	40	37	24	-

*, ** notes see Table 1 – objaśnienia w tabeli 1

*** % C extracted in organic C content – % C wyekstrahowanego w ogólnej zawartości C organicznego

compound transformations while composting is connected with intensive mineralization of organic compounds characterised by a simpler structure. Therefore, soluble carbon concentrations in compost are a good indicator of its stability. In the present research, the content of soluble carbon extracted with the mixture of sodium pyrophosphate and sodium base proved the largest in farmyard manure (Table 2). Compost (A) from plant wastes and other biodegradable wastes contained almost twice more soluble carbon than compost (B) made only of plant wastes. The smallest quantities of soluble carbon were registered in compost (C) produced from municipal wastes. Percentage of soluble carbon in total organic C was varied but did not exceed 35% of the total tested organic materials. In the present investigations, soluble carbon was extracted with a mixture of sodium pyrophosphate and sodium base, whereas according to WU and MA (2002) water and $0.1 \text{ mol} \cdot \text{dm}^{-3}$ are better extractants for assessment of compost stability.

Compost (A) produced with Mut Kyberferm technology contained the greatest amounts of total nitrogen, over twice as much as compost (B) manufactured using Horstmann technology and even 4-fold more than compost (C) produced from municipal waste using Dano technology. Nitrogen content in alkaline extracts from the analysed organic materials ranged between 2.0 g and $14.9 \text{ g} \cdot \text{kg}^{-1}$ d.m. The share of nitrogen extracted by sodium pyrophosphate and sodium base was varied, with the highest share found in farmyard manure and compost (A) produced from plant waste and other biodegradable components, (respectively, 45% and 40%). Transformations of nitrogen compounds are an inevitable element of the composting process and reveal a similar direction of changes as carbon compounds.

One consequence of diversified contents of carbon and nitrogen in the tested organic materials was the value of C:N ratio. The value approximating 15 is commonly regarded as an indicator of compost stability and may evidence that this material has reached maturity (IGLESIAS-JIMENEZ, PEREZ-GARCIA 1991). The value of C:N in the analysed composts turned out to be similar to that in composts of plant waste (B) and municipal waste (C) (11.6 and 12.9 respectively) and comparable with the values of this parameter computed for peat and farmyard manure. A significantly lower value was registered for this parameter in compost (A) obtained from plant materials and other biodegradable waste.

The three composts differed in respect of their humus fraction content. The largest content of humic acid carbon (CKh) was found in compost (A) ($67.4 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$), which was comparable to the amount assessed in peat ($52.9 \text{ g} \cdot \text{kg}^{-1} \text{ d.m.}$). Farmyard manure and compost (B) were characterised by a smaller content of humic acid carbon, whereas the smallest amounts of CKh were found in compost (C) from municipal waste.

Fulvic acid carbon content (CKf) was in each case lower than humic acid carbon content (Table 3). Comparable contents of fulvic acid carbon were found in composts (B) and (C). The highest quantities of fulvic acid carbon were assessed in farmyard manure and peat.

The value of CKh:CKf fell within a relatively wide range (for composts), i.e. between 2.29 and 8.26 (Table 3). Higher values of this parameter were characteristic for composts (A) and (B) produced from plant wastes than compost (C) manufactured from municipal wastes. The value of this parameter determined in farmyard manure (1.08) was significantly lower than assessed in composts.

Table 3
Tabela 3

Fractional composition of organic matter in the analysed organic materials ($\text{g} \cdot \text{kg}^{-1} \text{ d.m.}$)
Skład frakcyjny materii organicznej w badanych materiałach organicznych ($\text{g} \cdot \text{kg}^{-1} \text{ s.m.}$)

Determination Oznaczenie	Peat Torf	FYM Obornik	Compost – Kompost			SD**
			A*	B*	C*	
C Kh	52.9	49.4	67.4	43.0	13.3	20.0
%***	13	15	27	21	12	-
C Kf	22.3	45.6	12.6	5.2	5.8	16.7
%***	5	14	5	3	5	-
CKh:CKf	2.37	1.08	5.35	8.26	2.29	2.92
C nonhydrolyzing C niehydrolizujący	344	234	171	154	93	95
%***	82	71	68	77	83	-

*, ** notes see Table 1 – objaśnienia w tabeli 1

*** % C extracted in organic C content – % C wyekstrahowanego w ogólnej zawartości C organicznego

The highest amounts of non-hydrolysing carbon were recorded in peat and farmyard manure, respectively 82% and 71% in relation to total content of organic carbon (Table 3). A comparable content of non-hydrolysing carbon was found in composts from plant waste (A) and (B), where it was on average 43% lower than the amount assessed in compost from municipal waste (C).

Total concentration of lead in the composts was higher than in farmyard manure and peat (Table 4). Most lead was found in compost from municipal wastes (C) ($293.8 \text{ mg} \cdot \text{kg}^{-1} \text{ d.m.}$) and this content prevented agronomic use of this material (*Decree of the Minister...* 2001). Lead mobility in the analysed composts was low, irrespective of the extractant used, and generally did not exceed 8% (total for two fractions) of this element's total content. ROSIK-DULEWSKA (2001) also found small amounts of lead in exchangeable and carbonate fraction separated from composts produced from municipal waste. She found out that lead was mainly bound to iron and manganese oxides and to organic fraction. Relatively low mobility of lead in compost has been confirmed by the results obtained by DROZD et al (1996b), who found that during compost maturation the content of water soluble lead compounds changed the least.

Table 4
Tabela 4

Content of lead in the analysed organic materials ($\text{mg} \cdot \text{kg}^{-1} \text{ d.m.}$)
Zawartość ołowiu w badanych materiałach organicznych ($\text{mg} \cdot \text{kg}^{-1} \text{ s.m.}$)

Determination Oznaczenie	Peat Torf	FYM Obornik	Compost – Kompost			SD**
			A*	B*	C*	
Total Pb – Pb og.	8.9	4.9	12.8	14.2	293.8	127
Pb – H ₂ O	0.06	0.10	0.60	0.95	0.11	0.40
%***	0.7	2.0	4.7	6.7	<0.1	-
Pb – CaCl ₂	0.00	0.07	0.07	0.05	0.03	0.03
%***	-	1.4	0.5	0.4	<0.1	-

* ** notes see Table 1 – objaśnienia w tabeli 1

*** % C extracted in organic C content – % C wyekstrahowanego w ogólnej zawartości C organicznego

Total zinc concentrations in the composts were markedly different (Table 5). Compost (A) contained almost 7-fold less zinc, while compost (B) nearly 4-fold less of this element in comparison to the zinc content assessed in the compost from municipal waste (C). Total zinc concentrations assessed in the composts from plant waste (A) and (B) were lower than determined in farmyard manure. The quantities of zinc extracted by individual solutions were diversified, but more zinc (beside peat and compost B) was extracted with water. The amount of zinc extracted with the solutions applied (total for two fractions) and in comparison with total content was the highest for peat and compost (A). The results obtained by DROZD et al (1996b) concerning the dynamics of mobile zinc form concentrations during

municipal waste composting indicated a rapid decrease in concentrations of zinc form passing into water solution. These authors suggested that a decrease in large molecular humus compounds forming during transformation of composted biomass might have contributed to it. ROSIK-DULEWSKA (2001), who analysed composts produced from municipal waste, found that the main part of zinc is bound to Mn and Fe oxides. For comparison, in their studies on sewage sludge PIOTROWSKA, DUDKA (1987) found only 3% share of zinc in the exchangeable fraction, but due to its high total content, the absolute content of Zn in this fraction was significant. In sewage sludge zinc was also bound to iron and manganese oxides.

Table 5
Tabela 5

Content of zinc in the analysed organic materials ($\text{mg} \cdot \text{kg}^{-1}$ d.m.)
Zawartość cynku w badanych materiałach organicznych ($\text{mg} \cdot \text{kg}^{-1}$ s.m.)

Determination Oznaczenie	Peat Torf	FYM Obornik	Compost – Kompost			SD**
			A*	B*	C*	
Total Zn – Zn og.	17	629	177	322	1186	461
Zn – H ₂ O	0.85	20.75	13.21	9.50	4.67	7.71
%**	5.0	3.2	7.5	3.0	0.4	-
Zn – CaCl ₂	1.10	3.11	0.62	0.82	8.10	3.15
%***	6.5	0.5	0.4	0.3	0.7	-

* , ** notes see Table 1 – objaśnienia w tabeli 1

*** % C extracted in organic C content – % C wyekstrahowanego w ogólnej zawartości C organicznego

Total concentration of copper was the highest in farmyard manure ($368.20 \text{ mg} \cdot \text{kg}^{-1}$ d.m.) – Table 6. Between 1.5- and over 11-fold less copper was assessed in the composts. Such a high concentration of this metal in farmyard manure resulted from its origin and most probably from the kind of fodder fed to pigs. On the farm from which the farmyard manure originated the animals were fed intensively by concentrate feed mixtures amended with mineral and vitamin supplements in order to meet the animal nutritional needs. The analysis of copper extracted with water revealed the largest amounts of this metal in the extract from farmyard manure ($48.81 \text{ mg} \cdot \text{kg}^{-1}$ d.m.), even though the share of this copper form in the total content did not exceed 13% and was comparable with the quantities determined in the compost manufactured from green waste (A). The amount of copper extracted with CaCl₂ solution was considerably smaller and less diversified among the tested organic materials. The ratio of copper mobile forms (total of two fractions) to the total content was the highest in peat. In farmyard manure and the composts the value did not exceed 15%. Such a small content of copper in the extracts may suggest that at the final stage of composting large molecular humus compounds were formed, which affected solu-

Table 6
Tabela 6

Content of copper in the analysed organic materials ($\text{mg} \cdot \text{kg}^{-1}$ d.m.)
Zawartość miedzi w badanych materiałach organicznych ($\text{mg} \cdot \text{kg}^{-1}$ s.m.)

Determination Oznaczenie	Peat Torf	FYM Obornik	Compost – Kompost			SD**
			A*	B*	C*	
Total Cu – Cu og.	3.0	368.2	32.1	62.7	240.8	157
Cu – H ₂ O	0.92	48.81	4.44	3.80	1.58	20.7
%***	30.7	13.3	13.8	6.1	0.7	-
Cu – CaCl ₂	0.38	3.93	0.27	0.42	0.41	1.59
%***	12.7	1.1	0.8	0.7	0.2	-

* ** notes see Table 1 – objaśnienia w tabeli 1

*** % C extracted in organic C content – % C wyekstrahowanego w ogólnej zawartości C organicznego

bility of copper compounds. DROZD et al (1996b) pointed at similar dependencies when they observed a rapid increase in the copper concentration in an extract during the initial period of composting and its subsequent decrease after 6 months.

Total concentrations of cadmium were the lowest in peat – $0.33 \text{ mg} \cdot \text{kg}^{-1}$ d.m. (Table 7). The largest quantities were found in compost (C) from municipal waste ($5.88 \text{ mg} \cdot \text{kg}^{-1}$ d.m.), which made it impossible to use this material as a fertilizer (*Decree of the Minister 2001*). The cadmium content extracted with water was the highest in farmyard manure and the compost produced from green waste (A). The percentage of this cadmium form in the total content constituted, respectively, over 7% and over 8%. The content of the exchangeable cadmium fraction (extracted with $0.05 \text{ mol} \cdot \text{dm}^{-3}$ CaCl₂) was generally small and the

Table 7
Tabela 7

Content of cadmium in the analysed organic materials ($\text{mg} \cdot \text{kg}^{-1}$ d.m.)
Zawartość kadmu w badanych materiałach organicznych ($\text{mg} \cdot \text{kg}^{-1}$ s.m.)

Determination Oznaczenie	Peat Torf	FYM Obornik	Compost – Kompost			SD**
			A*	B*	C*	
Total Cd – Cd og.	0.33	1.61	1.41	0.84	5.88	2.21
Cd – H ₂ O	0.06	0.12	0.12	0.07	0.02	0.04
%***	18.2	7.5	8.5	8.3	0.3	-
Cd – CaCl ₂	0.02	0.02	0.01	0.00	0.08	0.03
%***	6.1	1.2	0.7	-	1.4	-

* ** notes see Table 1 – objaśnienia w tabeli 1

*** % C extracted in organic C content – % C wyekstrahowanego w ogólnej zawartości C organicznego

greatest amounts of this cadmium fraction were assessed in the composts from municipal waste (C). Much larger amounts of cadmium were determined in exchangeable and carbonate fractions in the studies on composts manufactured from municipal waste conducted by BARAN et al. (1999) and ROSIK-DULEWSKA (2001). However, it should be emphasised that those authors determined a much definitely higher total content of this element in the organic materials they analysed. On the other hand DROZD et al. (1996b) did not find cadmium concentrations in water extract, which they explain by the immobilisation of this metal in the form of carbonates at higher pH values.

CONCLUSIONS

1. Organic carbon content in composts depended on a type of composted waste – the smallest amounts of this component were assessed in the compost from municipal waste.

2. Organic matter transformations occurring during the composting process led to a systematic decrease in the amount of soluble organic compounds. The share of soluble carbon in the total content did not exceed 35% for all the tested composts.

3. The composts from plant waste were more nitrogen abundant than the compost from municipal waste, while the share of nitrogen extracted from the composts with sodium pyrophosphate and sodium base did not exceed 40%.

4. Analysis of fractional composition of humus compounds in all the composts revealed higher content of humic acid carbon in relation to fulvic acid carbon. The share of non-hydrolysing carbon in these materials was on average 70%.

5. The content of the most mobile heavy metal forms in the composts were low, which implied that these elements occurred in a form less available to plants.

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